Response GMD referee comments

legends:

- comments from referee
- response to referee comments
- modifications

The line number refers to the difference document.

RC1: Gabriel Barajas

The reviewer is very happy about the new version of the manuscript, which has been substantially improved, taking into account most of the comments from the three reviewers.

We thank the reviewer for his very positive feedback and for helping us to improve the manuscript.

Last minor comments:

(1) However, this reviewer is still not happy with the description figure, because each figure should be auto-explicative, explaining its content, context, and significance and acting as a standalone guide for the any potential reader.

Please, modify most of the figure captions.

We did our best to revise the figure captions, and we hope that the new version is now reaching the reviewer's expectations (please check the diff file to see the modifications) .

Figure 2. Flow chart of sedExnerFoam, illustrating the operations performed by the model during each time iteration.

Figure 3. Construction of the dual mesh from the horizontal projection of the finite-area mesh. The dual mesh is formed by connecting the centers of the original mesh faces and the centers of their edges, illustrated here for three polygonal faces.

Figure 4. Case directory structure for a sedExnerFoam simulation, organized into three folders: 0 for initial conditions, constant for modeling options and physical properties, and system for time control and numerical settings.

Figure 9. Schematic of the idealized dune migration case showing the main parameters and illustrating the relationship between bed elevation and depth-averaged velocity.

Figure 10. Bed level evolution of an initially Gaussian dune during an idealized transport scenario, comparing model results (solid lines) with the analytical solution (black dotted lines).

Figure 11. Comparison of bed levels in an idealized dune migration obtained from numerical simulations using three different advective schemes and two temporal integration schemes (Euler explicit top, Adams-Bashforth 2 bottom) with the analytical solution at intermediate (left) and near-breaking (right) times.

Figure 13. Time evolution of sediment mass per unit area, divided into suspended and deposited fractions, during deposition in a still basin. Relative error (%) of the total mass is shown by black crosses.

Figure 14. Sediment distribution in the domain at two times during sand deposition in an hourglass. At 3 s, a deposition mound forms from sediment deposited from suspension; at 10 s, all sediment has settled. Left: colors indicate water (blue); right: computational mesh deformation.

Figure 15. Temporal evolution of sediment mass per unit area, divided into suspended and deposited components, for sand settling in an hourglass. Relative error in total mass (%) is shown by black crosses. Suspended sediment is injected during the first 7 s and fully deposited before the end of the simulation.

(2) Some figures are still missing the legend (such as Fig 9 and 10).

Legends have been added to figures 9 and 10 and to the new figures introduced in section 5.

RC2: Sem Geerts

My second review will largely be in line with the first. I'm still of the opinion that the manuscript is promising and worth publication, but needs significant work to be of the quality expected by the journal. I appreciate the effort put into the second version of the manuscript. The writing has improved in the newly added text (as seen from the blue of the manuscript with tracked changes).

Some of my earlier remarks have not been dealt with satisfactorily. Some responses are fine, but stayed restricted to the rebuttal, and these comments or suggestions did not appear in the manuscript to help the reader. I still think the manuscript needs major revisions for publication.

I start with my general comments, which actually follow the exact same comments provided in my earlier review, with more explanation:

Many of the reviewers' comments focus primarily on the manuscript's presentation rather than its scientific content. We fully recognize the importance of clarity and presentation, and we have therefore devoted considerable effort to improving the English quality in this revised version.

We trust that these revisions will address the reviewer's concerns and that the manuscript will now meet the expected standards for publication.

General Comments

G1. The first comment is the same as in my previous review, to which I am not satisfied with the authors' response. No 3D or 2DH results are shown; it is also not mentioned that these are not shown intentionally. The word 3D is even in the title. Given the current writing, as a reader, I cannot be sure the model functions well for 2D bathymetries. Especially as the authors explicitly state that the bedload saturation process is only formulated for a 1D setting. Repeating, I would see either (1) a motivation in the manuscript explaining why showing a 3D model is not necessary, or (2) a reason how the results can be extended to 3D or how this is left for future work, or (3) see model

results from a 3D simulation.

To address the reviewer's concerns about the model's ability to handle 2D bathymetry, we have included a 3D simulation of the dune migration problem in the new subsection 5.3 of the revised manuscript. Some limitations of the model remain, and the revised text clarifies what is working and what needs improvement. We hope the reviewer is reassured by our honesty. If necessary, the reviewer can download the code on the github repository. That is one of the advantages of open science.

Modifications: new section 5.3 and the new 3D runs (lines 893 to 954 or the diff file)

G2. The quality of writing still concerns me, with examples highlighted below. In the rebuttal, the authors state they prefer to focus the manuscript as the "paper is already quite long", but consider it worthwhile to leave context to "to keep the seminal works in the presentation of the sediment transport community." I think much redundant information is provided; leaving this out will significantly reduce the length of the paper. Also repeating the statement in my first review, either (1) add the historical framing to the aim of the overall paper in the introduction, or (2) remove the historical context as it does not contribute scientifically. Overall, I leave the decision on the style of writing and providing the reader with all the options that are not implemented to the editor. However, I think the quality of English needs to be improved to increase readability. Please consider using language support or a grammar tool (e.g. Grammarly). See the list of suggestions below.

Regarding the reviewer's comments on the quality of the English, we acknowledge that there was room for improvement. Following the reviewer's suggestion, we have used Grammarly (free version) to carefully revise the syntax and spelling throughout the manuscript.

With respect to the reviewer's concern that "leaving this out will significantly reduce the length of the paper," we respectfully note that the revisions have actually allowed us to save approximately 10 lines in the manuscript (as detailed below)."

List of historical sentences removed from the previous version:

line 112: It was first introduced by Menter (1994) and was initially derived for aerodynamics studies.

line 185: ... which was first proposed by Exner (1920). In their article, Paola and Voller (2005) mention that Felix Exner initially suggested that the bed elevation was evolving proportionally with the divergence of the mean flow velocity, but made clear that the mean flow acted as a proxy for the sediment flux.

line 198: In the 1930's, Shields made measurements of the motion threshold already highlighted by Du Boys in 1879 (Hager, 2005).

line 201: Albert Shields showed that the critical Shields number is Reynolds dependent, leading to the development of various empirical formulas trying to estimate ϑ_c. Different formulations based on the dimensionless sediment particle diameter $D*$ (Eq. 9) have also been proposed in the literature, such as in the work of Brownlie (1983) and Soulsby and Whitehouse (1997).

G3. Model performance has been added, which I appreciate. I think the framing should be more embedded rather than a separate, stand-alone sentence at the end of every paragraph. Furthermore, as stated in my first review, I think a comparison or discussion of the computational speed is valuable. 50 seconds of physical simulation time taking 10h of calculation time seems like a lot to me, similar to the computational time required for the migrating dune. These simulations are all RAS, let alone what the computational time will be for LES. A discussion on whether the provided model is still usable for most engineering applications is fitting.

The model is not expected to be able to tackle any engineering problem at this stage of development. The purpose of the model is to be an intermediate tool between large-scale models typically used for engineering applications, such as TELEMAC3D, and fine-scale two-phase flow models, such as sedFOAM. As this article is the first one associated with the sedExnerFoam model, the optimization of the computational efficiency has not been addressed yet. This is left for future work, and a few perspectives to improve the numerical efficiency have been added to the discussion section of the manuscript (new section 6).

Lines 958 to 995 (of the diff file):   The newly developed solver, sedExnerFoam, shares several characteristics with existing three-dimensional morphodynamic models \citep[e.g.]|]| {liu2008;Jacobsen2014a,jacobsen2014b,Baykal2015}, while incorporating a number of methodological and numerical developments. [...] In this context, sedExnerFoam is intended to contribute as an intermediate-scale modelling tool and to support upscaling approaches such as those presented previously.

G4. There is still no discussion. I expect an extensive discussion of the results after Section 5, before the conclusion (not integrated into the conclusion). Especially, as the focus of the paper is to provide ~~in~~ an open-source model alternative, a section with outlook, model improvements, and next steps would be appropriate.

As requested by the reviewer, the revised manuscript now includes a section "discussion" and another section "Summary and outlook".

Section 6 Discussion (Lines 958 to 995)

Section 7 Summary and Outlook (Lines 996 to 1045 of the diff file)

Medium comments

Below are some comments provided that I think require a significant amount of work and can significantly change the overall structure of the report. The numbers below refer to the linenumbers.

- 171-193, rewrite. The order of appearance is incorrect. You claim in 172 that table 2 shows q_b, but table 2 shows phi_b. In 183 you claim table 2 contains theta_c, but table 2 shows theta_c^0. Consider first introducing theta_c^0, and then how it relates to theta_c (eq 12)

The text has been changed according to the reviewer's comment, and the critical Shields number on a flatbed, theta_c^0, is introduced before the slope correction.

line 198 (of the diff file version): Sediment transport initiates when the bed shear stress exceeds a critical value, referred to as the motion threshold and expressed in dimensionless form by the Shields number ϑ (Shields, 1936). The corresponding critical value is known as the critical Shields number ϑ_c. This threshold depends on fluid and sediment properties as well as on the local bed slope. For a flat bed, the critical Shields number, denoted as ϑ_{c0}, can be estimated using empirical formulations, many of which are based on the dimensionless sediment particle diameter D_*, such as the one proposed by Soulsby and Whitehouse (1997):

line 223 (of the diff file version): Moreover, the influence of bed slope requires additional corrections. The effect of local bed slope is incorporated through a correction to the critical Shields number proposed by Fredsoe and Deigaard (1992):

- 201 the authors talk about "user", but this section contains the "Mathematical description". To me, as the reader, the code does not exist yet. This also relates to the very technical references in Table 2 like bedloadProperties, which the reader does not yet know what it is. Please consider introducing the overall structure of the code first, which then provides the complete structure of the model setup in section 2. Alternatively, only focus on the mathematical model, and do not show any code-specific terminology yet. I think this requires careful attention.

We agree with the reviewer that the two Tables relative to closures should be moved to the section "Numerical implementation" as well as all references to the user and the code. This has been done in the revised manuscript (see the diff file for modifications).

- 221-224 Here the authors mention that there exists no 2D formulation, how can I

now be sure that the model works for 2D bathymetries?

There are different possible mathematical forms for the 2D formulation of the bedload flux saturation equation, but we haven't found references in the literature showing one of them. In this revised version of the manuscript, a 2D implementation of the saturation was implemented, and it is used to produce the 3D results in the application section relative to dune migration (new section 5.3). The presentation of the bedload flux saturation equation in the numerical model description was modified accordingly.

line 252 to 262(of the diff file): One last aspect, which is often neglected when modeling sediment transport in water but is widely used in aeolian transport, is the saturation of the bedload flux. The adjustment of qb toward its saturated value qsat is commonly expressed in 1D (Charru, 2006; Charru et al., 2013), however, in this work, the following 2D formulation is proposed:

equation (16)

where qsat is the saturated flux, Tsat the saturation time, and Lsat the saturation length. When taking the saturation into account, the saturated flux qsat is computed from the bed shear stress (see Eq. 14) and the bedload flux qb is the solution of Eq. 16. Similar to the Exner equation, the saturation equation is solved on a horizontal plane after projection.

- 390 + 407 The method to deal with non-erodible layers is not embedded in the manuscript well, while this is not trivial. Is this also really a boundary condition or does this change the physical processes? Please reconsider the framing in the manuscript.

As in most morphological models, such as openTELEMAC or Delft3D, the sediment availability is checked after the bedload flux calculation and before the bed update. A short description has been added to the manuscript.

line 439 to 442 (of the diff file): When a rigid bedrock is specified, the model restricts erosion to a predefined depth, ensuring that the non-erodible layer remains unaffected. This is achieved by iterating over all edges of the finite-area mesh and limiting the bedload flux whenever the sediment volume between the upwind face and the rigid bed is less than the flux through the edge. The initial time directory is read at the start of a simulation, providing the baseline from which the solution begins to evolve.

- Figure 13 uses a time integration scheme that was shown by Figure 14 to be the best. Re-order the section. First show about the time-integration schemes.

The purpose of this Figure is to illustrate the problem and show a working simulation, before presenting the sensitivity analysis to numerical schemes and mesh resolution. We prefer to keep this order of presentation.

- Section 5 contains only a subsection 5.1, no 5.2. -> Restructure

Section 5 has been completely rewritten and now includes three sub-sections:

5.1 Experimental configuration

5.2 2D numerical simulations

5.3 3D numerical simulations

Please see the revised manuscript to read the modifications.

- Section 5 does not present the used mesh

A visualization of the mesh is now shown in the newly added Figure 17.

Specific comments

Below are line-number-specific comments that require careful attention.

- Use of references is inconcistent, sometimes it is "equation 7", sometimes "Eq. 7", rephrase everywhere. Just like section and Section.

Done

- 54 remove the sentence about scour, the manuscript does't do anything with it.

Ok, the part in the introduction which mention scour has been rewritten. Scour is now only mentioned as an initial motivation for the development of the model and as an example among others.

line 53 (of the diff file): While its development was initially motivated by the need to study scour around hydraulic structures, the model is intended as a more general tool for simulating sediment–flow interactions, such as studying the formation and migration of bedforms in channels, assessing sediment deposition and erosion patterns in rivers, and analyzing sediment accumulation in reservoirs.

- 73-80 use subsection references as a guide for readers, e.g. "beginning with the hydrodynamics in 2.1"

Done

- 91-92: how does this show? Is the density constant? Please explain in the manuscript.

Correct, the fluid density is considered constant.

line 98 to 100 (of the diff file): At this stage of model development, no feedback of the suspended load on the hydrodynamics is considered, \textit{i.e.} the fluid density ρ_f is assumed to be constant, an assumption appropriate for dilute suspensions where density effects and particle drag are negligible.

- 104: "only the ... is used in this work" -> does this mean the others do not work or can the user still use them? Please explain in the manuscript.

The user remains free to employ alternative turbulence models. The manuscript does not imply that only the k−ω SST model is applicable; it is simply the model adopted for the present study. The text has been modified to make this statement more explicit.

line 111 to 113 (of the diff file): Of the various turbulence models available for the RAS approach in OpenFOAM (k −ϵ, k −ω, RN G k −ϵ ...), only the well-known k − ω Shear Stress Transport (SST) model introduced by Menter (1994) is employed in this study, although the other turbulence models available in openFOAM are also compatible with the solver.

- 106 "and was initially derived for aerodynamics study." Not sure why this is relevant

We do not understand the reviewer's main objection to historical references to the origins of models. To avoid any misunderstanding, we have removed the reference.

- 104-113 can be combined into a single sentence: "The k-omega SST model employs the strengths of the k-epsilon model (Launder and Spalding, 1983) to accurately capture free shear flows, and k-omega model (Wilcox et al., 1998) to capture adverse pressure gradients and boundary layers, combining them using a blending function (Menter 1994)." This is one of the examples where to my opinion many redundant sentences are used.

We do not understand the reviewer's argument. We have left the text as is.

-Table 1: parameters d, n and c^max_s are not explained in the manuscript yet when this table shows.

Done, d is introduced in the text after the expression of the dimensionless diameter. As Table 2 as been move to section 3, and c^max_s is introduced in Section 2, there is no issue.

line 161 (of the diff file): where d is the grain size

- Equation 9, parameter d is not explained.

Same as previous response

- Remove figures 2, 3 and 4. You claim your paper is getting long and to me they do not contribute to the story.

Done

- 171-180, properly introduce tau_b the first time you mention it.

τb is already introduced just before the Shields number at the beginning of section 2.4.2

line 198: Sediment transport initiates when the bed shear stress τb exceeds a critical value,

- Table 2 contains varpi, eta_b which are not introduced in the text yet when the table is mentioned.

This issue no longer exists now that Table 2 has been moved to the third section.

- Table 2 misses fixedvalue in the shields number formulations.

Done, Table 2 now includes the open fixedValue for the critical Shields number.

- Table 2 should mention theta_c^0 and phi_b in the caption.

Done

Table 2. Available formulas in sedExnerFoam to compute the critical Shields number on a flatbed ϑ_c^0 and the dimensionless bedload flux ϕ_b from the Shields number ϑ_c from fluid and sediment properties, Models are selected in bedloadProperties using the entries criticalShieldsModel and bedloadModel.

- 219 q_sat is not boldface, it is 1D.

In the new version, it is bolface since the formulation presented is now 2D.

- 235 "However, this boundary condition is not suitable for cases in which the assumption of local equilibrium at the reference level does not hold." Circular reasoning, rephrase.

This sentence does not demonstrate circular reasoning; it presents a conditional statement, explaining that the boundary condition fails when a specific assumption (local equilibrium) is violated. It does not assume what it is trying to prove; rather, it explains a limitation based on a criterion. Circular reasoning is therefore not a valid criticism. However, it is true that the sentence is closely linked to the previous one, and the wording could be clearer. This has been addressed.

line 273 (of the diff file): This development has been adopted in many sediment transport models, which define the boundary condition cs $(\delta z_b \ast)$ = c$\ast$b based on the assumption of equilibrium at the reference level. The boundary condition, however, may not be valid in cases where this local equilibrium assumption is violated.

- 242 – 248 move to separate discussion.

We do not believe that this material needs to be moved to a separate discussion section. The text simply recalls the modelling choices commonly adopted in similar sediment transport models, prior to introducing the approach implemented in *sedExnerFoam*. It also serves to clarify the difficulty associated with imposing a bed boundary condition at a reference level that does not coincide with the bottom of the computational domain.

Lines 272 and 275 are exactly the same, rephrase the paragraph.

We understand the criticism of this paragraph. However, they are not exactly the same. The first sentence states the general issue: "To address difficulties in suspending material from the bed to the water column when using a fine grid resolution and low roughness Reynolds number: ks+ = ks u∗/ ν , an additional near-bed diffusivity for suspended sediment ϵw was introduced in the model."

Then the following sentence explains why this issue exists, and what difficulties are encountered in suspending particles from the bed to the water column. It comes from the fact that turbulence vanishes close to the bottom for flows that are not hydraulically rough. "In the smooth and intermediate roughness regimes, the eddy viscosity vanishes within a thin layer near the bed. When the mesh resolution is sufficiently fine such that the first cell lie within this layer, the eroded sediment tends to remain confined to this cell rather than being transported upward into the water column."

Only the last sentence was changed from "To mitigate this issue, an additional artificial diffusivity is introduced in the near-bed region..." to "The additional diffusivity introduced for suspended sediment is defined as follows:" (line 316 of the diff file)

299-301 Vague, I do not understand it. Rephrase.

It has been rephrased in the new version of the manuscript.

Line 340 (of the diff file): The discretization of the partial differential equations using the finite area method was originally developed to account for surface curvature; however, curvature effects are not considered in the present treatment of bed morphology evolution. Accordingly, the Exner equation is solved on a plane projected normal to the gravity vector g.

302-310 To my knowledge, you have not written or adjusted the PIMPLE algorithm. Please just mention you use it and cite.

Unfortunately, there is no formal publication associated with the PIMPLE algorithm, as it was developed by the original *OpenFOAM* developers and is not linked to a specific peer-reviewed article. By contrast, the PISO and SIMPLE algorithms are classical pressure–velocity coupling methods that are widely documented and used in CFD. Since PIMPLE is specific to *OpenFOAM* and may be less familiar to readers outside that community, we believe that providing a brief explanation of the algorithm in the manuscript is justified and not excessive.

Figure 5 needs more explanation in the caption

The caption of the figure has been revised

Figure 2. Flow chart of sedExnerFoam, illustrating the operations performed by the model during each time iteration.

Figure 5 shows q_sat as boldface, but you mention that it only exist in 1D formulation. Please explain in the manuscript.

In the revised version of the manuscript, the saturation formulation is no longer one-dimensional. The saturated bedload flux, qsat, is now treated as a vector quantity and is therefore represented in bold font throughout the manuscript.

319 e_g is already defined in line 136.

Thanks, its definition has been removed the second time.

321 + 547 and elsewhere. Consider whether it shouldn't be "integration" every time you talk about "discretization" in the sense of Exner. For example, "Adam Bashforth 2 integration scheme".

The word integration is used instead of discretization when referring specifically to the temporal schemes.

line 363(of the diff file): The users have the choice to use either an explicit Euler scheme or a second-order Adams-Bashforth scheme for temporal integration.

line 600 (of the diff file): A second-order Adams-Bashforth scheme is used for time integration and a linear-upwind scheme for the advective term discretization.

Figure 11. Comparison of bed levels in an idealized dune migration obtained from numerical simulations using three different advective schemes and two temporal integration schemes (Euler explicit top, Adams-Bashforth 2 bottom) with the analytical solution at intermediate (left) and near-breaking (right) times.

line 616 (of the diff file): From the results presented in Figure 11, the combination of a second order second-order Adams-Bashforth scheme for the time discretization integration and a linear or linear-upwind scheme for the bedload flux discretization, both being second order...

326 mentioned 1D cases and 3D cases, what about 2D cases? Or do you mean

2D instead of 3D because the bathymetry is 2D right? Please explain in the manuscript.

Yes, the reviewer is correct, a 1D case would be 0D for the Exner equation, with only one scalar value for the bed level. A 2D case would be 1D for the Exner equation, and a 3D case would be 2D for the Exner equation.

line 371 (of the diff file): Although mass-conservative for 1D bathymetries on structured meshes, the method fails to preserve mass for 2D bathymetries on unstructured meshes.

341 – 344 explain how the interpolation leads to a filter, what kind of filter is this. At this point it is also not clear whether it is desired or an unwanted artefact.

The sentence was extended to provide an explanation of how the interpolation steps filter the bed level increment.

line 387 (of the diff file): This interpolation method is mass-conservative and also acts as a filter, as the bed increment is interpolated back and forth between the face centers, where the Exner equation is solved, and the vertices, where the mesh motion is imposed, which in turn updates the positions of the face centers.

370-375 move to a separate discussion. Just mention it is not implemented and refer to the discussion where you discuss the alternatives and implications.

This paragraph has been removed from this section.

Figure 7 needs more explanation in the caption

Done

Figure 4. Case directory structure for a sedExnerFoam simulation, organized into three folders: 0 for initial conditions, constant for modeling options and physical properties, and system for time control and numerical settings.

406 Morphological acceleration factor is never explained in the manuscript. Explain the reader what it is and how it is used.

The text has been slightly revised to clarify that the morphological acceleration factor is simply a scaling factor applied to the bedload flux.

line 457 (of the diff file): use a morphological acceleration factor that scales the bedload flux, and ...

438 It is not to validate the whole model, only the suspended load part.

Correct, the text has been modified.

447 z+ is the non-dimensional distance, rephrase.

We do not understand what the problem is here; it is only stated that the resolution is kept at z+=1. And the definition is given in the next sentence: "Here, $z+ = u*z1/\nu$ denotes the distance of the first cell center from the bed boundary in wall units, where z1 is the distance to the sediment bed boundary."

459 qualitatively should be quantitatively right?

Right, it has been corrected.

474 are these hypotheses or assumptions? In line 482 you call them assumptions.

Now, only the word assumption appears in the next

481 "They performed a separation of variable and used the Sturm Liouville theory to obtain a solution which only depends on the Rouse number." Not sure why this is relevant. Remove.

Why would it not be relevant to briefly describe how the pseudo-analytical solution, used for comparison with our numerical results, is obtained? As this is just one sentence: "They performed a separation of variables and used the Sturm-Liouville theory to obtain a solution, which only depends on the Rouse number.", we have left in the manuscript.

489 "from the inlet and last the turbulent eddy-viscosity" do not understand the word "last" here

The text has been modified

511 "for instance by playing with the boundary conditions" playing is informal, rephrase.

Done

line 564 (of the diff file): A better agreement could yet be found, for instance, by adjusting the boundary conditions ...

512 is an "adjustment parameter" not just a calibration parameter?

Ok, it has been changed

line 566 (of the diff file): Another calibration parameter is the reference concentration at the reference level, which is the bottom boundary condition of the pseudo-analytical solution.

530 – 532 remove "A shock occurs ... one negative slope" this is not relevant.

The sentence explains the condition under which a shock forms in the solution of the wave equation. Two lines later, it is noted that the initial condition provided for the problem satisfies this shock condition. So, the 2 lines you indicate are perfectly relevant to us and we have decided to keep them in the revised manuscript.

563 you explained to me in the rebuttal what linear-upwind is, but to me as a reader it is still not clear. Add it.

The different options implemented for the discretization of the divergence term in the Exner equation have been added to section 3.2 as follows:

Line 365 (of the diff file): The discretization scheme for the divergence flux term can be either centered (i.e. linear), upwind first order or upwind second order (i.e. linear upwind).

Figure 15 not clear what n_x is.

n_x is the number of faces that make up the finite-area mesh. This has been added to the figure caption.

Figure 12. Root mean square error for different combinations of numerical schemes and mesh refinements. The time step is constant (δ t=0.05 s for all simulations, with only the number of faces (nx) in the finite area mesh varying. The maximum Courant number, based on the bedform celerity, is indicated on the top axis.

Figure 15 I do not understand the top y-axis.

The top axis indicates the maximum Courant number based on the bedform celerity. The caption of Figure 12 has been modified to indicate what the top axis is. See response to the previous point.

600 – 609. Order of presentation needs to change. You first talk about input, then about results "pronounced slopes form", and then you go back to the input parameters.

Done, the order has been changed.

line 657 (of the diff file): Another settling case is presented, this time a 2D case with non-uniform settling. The computational domain is conic-shaped, wider at the bottom (5cm) and narrower at the top (1cm). Initially, only water is present in the domain. The repose angle is taken equal to $\beta_r = 32°$. The sediments diameter is d = 0.29 mm and their density $\rho_s = 2600$ kg.m-3 . The sediment settling velocity $w_{s0} = 3.5$ cm.s-1 is computed using the formula from Fredsoe and Deigaard (1992) (see Table 1) and is considered uniform as the hindrance effect is not taken into account. A constant flux of sediment is injected during 7 seconds by imposing a constant suspended sediment volume fraction at the top boundary $c_s = 0.05$. The sediments settle under the action of gravity and deposit on the bed. Because the settling is not spatially uniform, pronounced slopes form at the margins of the deposition mound, where avalanching occurs, producing a conical shape similar to that seen in an hourglass. The simulation is then run for 3 more seconds so that all sediments have settled by the end of the simulation (see Figure 14).

601 + 607 +612 contain the same information: "sediments are injected at the top boundary condition with a constant concentration" and "A constant flux of sediment is injected during 7 seconds" and "At 7 seconds, sediments stop being injected"

Done, the text has been modified, see the response to the previous point.

631 "the dune morphology rapidly changes from an initial conic shape obtained by deposition of sediments in still water" I do not understand this sentence, rephrase.

It only means that, initially, the dune is conic-shaped and that its morphology changes during the first phase of the migration. The text has been slightly modified.

line 697: During the initial phase, the dune morphology evolves rapidly from an initial conical shape formed by sediment deposition in still water. After this transient phase, the dune reaches a stationary state, migrating at a constant speed in the flow direction with minimal deformation.

Page 31 could you explain me and the reader in the manuscript why you chose to do 2DV modelling and make a source term for the walls instead of just modelling the walls directly with the 3D model?

Ok, it allows to use only a 2D mesh instead of a 3D one. This allows for faster and less costly simulations. It was already written in the text.

line 740: The main advantage of accounting for lateral friction as a source term is that it enables the use of a 2D mesh, which significantly reduces the computational cost of the simulation compared with a 3D simulation.

666 "As the dune is transported by the flow", the dune is not transported by the flow. The dune migrates due to a divergence in sediment transport (by the flow), causing bed level changes. Rephrase.

Done

line 715: As the dune is migrating downstream, the particle bed is compacting, and the sediment volume fraction in the bed increases, resulting in the apparent dune volume decreasing over time until the volume fraction reaches a constant value of about csmax0.6.

Figure 20 I don't get why you show the reader this figure. Also in the rebuttal you claim that "OpenFoam has been validated extensively for the flow hydrodynamics in various configurations.", so you don't need to show this right?

The figure shows three snapshots of the dune and the flow streamlines at different times during the migration process. It is the only figure illustrating flow detachment and the recirculation cell, while also clearly showing the initial condition and the evolution of the dune morphology over time. The dune evolves from an initial conical shape to the asymmetric stationary shape it eventually adopts. We do not see how this figure could be irrelevant.

Figure 20 needs more information in the caption

Done

Figure 18. Representation of the dune at different times (0, 15, and 30 seconds) during the migration process. The flow streamlines highlight flow detachment near the dune crest and the recirculation cell downstream. Starting from an initial conical shape, the dune evolves into an asymmetric, stationary form.

Figure 22, top y-axis is unclear with only one value shown.

Ok, it has been changed in the new version of the manuscript. See figure 20.

752 + 757 contain the same information: "It was also found that the inertia of sediments transported as bedload was essential" + "It was also found that the inertia of the sediments transported as bedload is essential for describing"

Done, it has been corrected.

755 "the turbulence model and the numerical scheme used to discretize the advection term in the fluid momentum equation must be chosen carefully" you did not vary the turbulence model if I understood correctly.

In the present study, the turbulence model was not varied; however, previous tests indicate that the choice of turbulence closure can influence the location of flow detachment and, consequently, the overall morphodynamics of the problem. For example, using a $k-\varepsilon$ model could result in a flow that does not detach from the dune crest. Here, we mention the turbulence model primarily to inform the reader that it also affects the hydrodynamics.

767 "Beyond possible future developments, such as the addition of a free surface, accounting for multiple grain sizes or modelling cohesive sediments" This deserves its own section in the discussion, future model development.Technical

Done, there is now a section discussion at the end of the manuscript.

Below are purely textual comments.

41: 3D models -> 3D hydrodynamic models

The models cited here are also sediment transport models.

46 integration -> implementation / consideration

101 two-equations models

Done

155, vague, rephrase

Ok

line 174 (of the diff fime): The final key aspect of this approach is the enforcement of the bed boundary condition, i.e., the exchange of mass between the sediment bed and the suspended load. This topic is discussed in Section 2.4.3, which addresses erosion and deposition rates.

165 remove "in their article"

Done

165 Felix Exner -> Exner

Done

180 Albert Shields – Shields

Done, there is no more mention of Albert Shields

228 remove "in his work"

Done

245 need -> needs

Done

245 a bad -> bad

Done

255 non physical -> non-physical

Done

255 "important" vague and informal, rephrase

Done

line 295 (of the diff file): The limiter ensures that cb* remains physically realistic when the bed shear stress is high

255 remove "in their work

Done

334 faces -> face

Done

351 "The mesh vertices new coordinates" unclear, should be " vertices' "?

Done

370 remove "in their work"

Done

382 "main folders." -> "main folders, further explained below."

Done

388 k -> k (k)

Done

420 "Then" -> "Next,"

Done

428 results -> result

Done

487 hypothesis -> hypotheses or assumptions

Done

Figure 9 pseudo-analytical

Done

520 considered -> assumed

Done

512 remove "the"

the?

528 bed form -> bedform

Done

534 top of the dune -> dune crest

Done

537 "it is needed to" informal, rephrase

Done

551 "becomes important" informal rephrase.

Done

554 "brings up" rephrase

Done

557 filter, however -> filter. However

Done

573 z_b^n -> z_b^n |_f

Done

617 "verified" inappropriate use of the word, rephrase.

Done

630 "Sandoungout and called" -> Sandoungout, called

The text has been modified.

line 693 (ot the diff file): The author identified the existence of two regimes: the stationary regime and the mass loss scenario.

631 "first one", no idea what this means

The text has been modified

In the present work, the focus is on the stationary regime, which exhibits two stages. During the initial phase, the dune morphology evolves rapidly from an initial conical shape formed by sediment deposition in still water. After this transient phase, the dune reaches a stationary state, migrating at a constant speed in the flow direction with minimal deformation.

636 "the top by a rigid lid and is entirely filled with water." -> "the top by a rigid lid" (by definition of the rigid lid)

Ok, done

636 "sphericity. Their" -> "sphericity, with"

The text has been modified.

Line 703 (of the diff file): The granular material consists of highly spherical glass beads with a diameter of d=0.4mm and a density of ρs=2500kgm−3.

640 compare – compared

Done

662 remove m_0, has no purpose

Done

672 – 673 regarding ... domain. Awkward sentence, rephrase

Done, the text has been rewritten.

line 762 (of the diff file): The inlet boundary conditions are imposed as follows: a uniform velocity is applied u = 0.43 m.s−1 ; Dirichlet boundary conditions are used for the turbulent quantities: k = 0.001 m2 .s−2 and ω = 15 s−1 . It corresponds to a turbulent intensity It 0.06. Those values were chosen after simulating the flow in the flume without particles, and it has been verifiedthrough a sensitivity analysis of the upstream domain length that the solution does not change when using a longer domain (not shown here).

675 boundary. It corresponds -> boundary, corresponding

The text has been changed, see response to the previous point.

680 remove "accelerate and"

The text has been modified.

line 752 (of the diff file): Since the time required for the flow to accelerate and reach the target mean velocity is unknown, an alternative initialization was chosen for the problem.

685 "tunes", again a different word for calibrate?

This part of the text has been entirely rewritten and is now within a subsection 5.2.3 Sensitivity analysis and bedload flux saturation effect

693 under estimate -> underestimate

Done

705 "A last key parameter is the formula chosen to calculate the bedload transport" a formula is not a parameter, rephrase

The text has been modified

712 "a last", rephrase, 705 already mentioned a "last" point.

Done, it has been rephrased.

line 848 (of the diff file): The most critical and original mechanism that is accounted for in the present model is the bedload flux saturation, which represents the particle's inertia with respect to the fluid flow.

727 unchanged and regarding -> unchanged. Regarding

Done, the text has been changed.

730 n the case -> In the case

Done

694 unclear what "wall unit" is.

It corresponds to the dimensionless wall distance as already introduced in the manuscript.

733 experience -> experiment

Done

762 Using the -> The

Done

Commas :

More commas are required to improve the readability and proper English of the manuscript. Below are some examples. Please critically go over the entire manuscript to find cases I missed.

The commas were reviewed throughout the entire manuscript with the help of the free version of Grammarly.

- 87 (LES),
- 102 TKE, respectively.
- 138 fall,
- 144 fluid, respectively.
- 149 one,
- 182 literature,
- 182 Renolds-dependent,

- 215 water,
- 238 cells,
- 245 regions,
- 256 0.3, which
- 274 fine,
- 278 equation 7,
- 296 problems,
- 311 computed,
- 312 Lastly,
- 384 names 0,
- 418 presented,
- 428 gravity,
- 429 w_s,
- 449 instead,
- 486 identical,
- 499 inlet,
- 505 inlet,
- Figure 9 enforced,
- 512 level,
- 548 solution,
- 549 time,
- 554 prediction,
- 558 instabilities,
- 611 1.14s,
- 637 7.67cm.s−1,
- 639 2.78cm.s−1,
- 659 improved,
- 666 flow,
- 667 increases,

- 671 one,

- 693 and,

- 702 table 2,

- 703 dune,

- 723 x_h,

- 727 velocity,

- 729 load, respectively

- 695 surprisingly,

- 733 and,